



Study of $Z\gamma$ Production at CDF

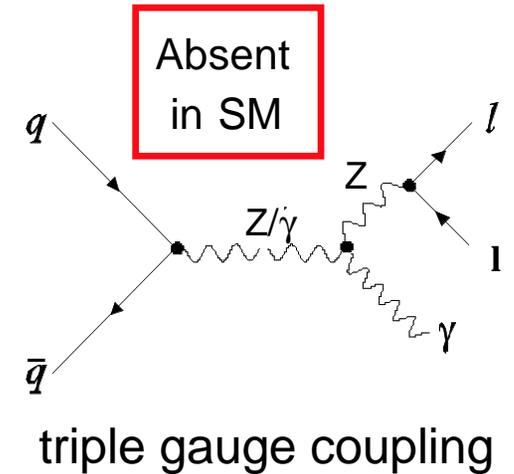
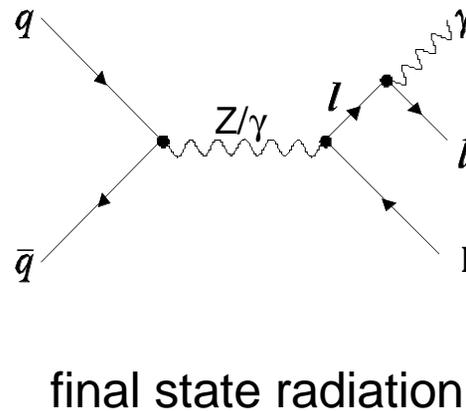
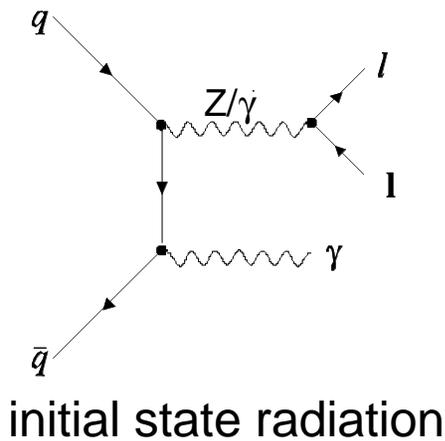
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for the CDF Collaboration

Oct. 31, 2006 @ DPF

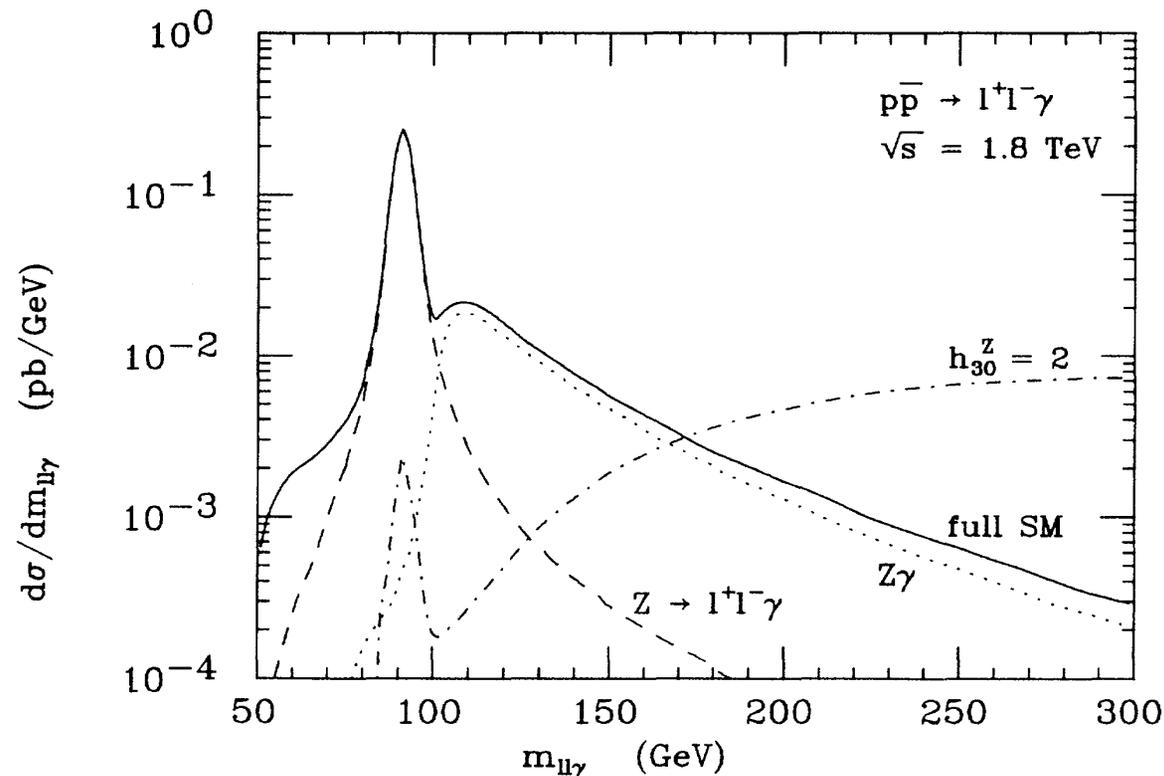
- Introduction
- $Z\gamma$ Event Selection
- Background Contribution
- $Z\gamma$ Cross Section
- Kinematics Distribution
- Summary

Introduction: $Z\gamma$ production

- $p\bar{p} \rightarrow e^+e^-\gamma X$
- Photon:
 - initial state radiation (ISR)
 - final state radiation (FSR)
- Triple gauge-boson couplings:
 - no $ZZ\gamma$ couplings in SM
 - search for anomalous couplings



U. Baur et al., PRD47 V11 4889



- $ll\gamma$ Mass distribution in $Z\gamma$ production
 - Solid curve: SM; dashed line: FSR; dotted line: ISR
 - dash-dotted curve: anomalous couplings contribution
- **High mass region** is most sensitive to **anomalous couplings**

Previous CDF Measurement with 200 pb⁻¹ of Data

	$e^+e^- \gamma$
N_{sig}	31.3 ± 1.6
N_{bkg}	2.8 ± 0.9
$N_{sig} + N_{bkg}$	34.1 ± 1.8
N_{data}	36
$A \times \epsilon$	3.4%
$\sigma(e^+e^- \gamma)(\text{pb})$	$4.8 \pm 0.8(stat) \pm 0.3(sys) \pm 0.3(lum)$

H. Hayward et al., PRL 94, 041803(2005)

- Previous measurement(200 pb⁻¹)
 - Observe 36 events, limited by statistics
- Current measurement, data collected in 2002 - 2006
 - 1.1 fb⁻¹ of data : x 5
 - Expand $Z\gamma$ acceptance : x 2
 - Observe 390 events

$Z\gamma$ Event Selection

Photon selection:

- $E_T > 7$ GeV central photon ($|\eta| < 1.1$)

Loose Z selection :

- Two $E_T > 20$ GeV electrons :
 - One electron in central detector region ($|\eta| < 1.1$)
 - The second electron in central or forward detector region ($|\eta| < 2.8$)
 - Apply loose electron selection criteria
- Measure the inclusive Z cross section as a cross check

$Z\gamma$ event selection

- Photon well separated from electrons
 - $\Delta R(e, \gamma) = \sqrt{(\eta_e - \eta_\gamma)^2 + (\phi_e - \phi_\gamma)^2} > 0.7$
- $M_{ee} > 40$ GeV/ c^2

$Z\gamma$ acceptance:

- In a sample of ~ 90 K Z events, 390 $Z\gamma$ events observed.

$Z\gamma$ Background Estimation

Very clean channel, only two significant backgrounds:

- $Z + \text{fake photon}$
- $\text{photon} + \text{fake } Z$

$Z + \text{fake photon background } (\sim 10\%)$:

- Jet fakes a photon
- Measure Photon fake rate from jet samples
 - Fake rate: $\sim 0.3\%$ at $E_T^\gamma = 10 \text{ GeV}$; $\sim 0.05\%$ at $E_T^\gamma > 25 \text{ GeV}$
- Apply photon fake rate to jets in $Z+\text{jets}$ events in electron-triggered samples

$\text{photon} + \text{fake } Z \text{ QCD background } (\sim 4\%)$:

- Jet fakes an electron
- $\sim 9\text{K}$ fake Z background events in the inclusive Z sample ($\sim 90\text{K}$ events)
- $\sim 0.1\%$ of these fake Z events has an additional photon

Measure $Z\gamma$ Cross Section with 1.1 fb^{-1} of Data

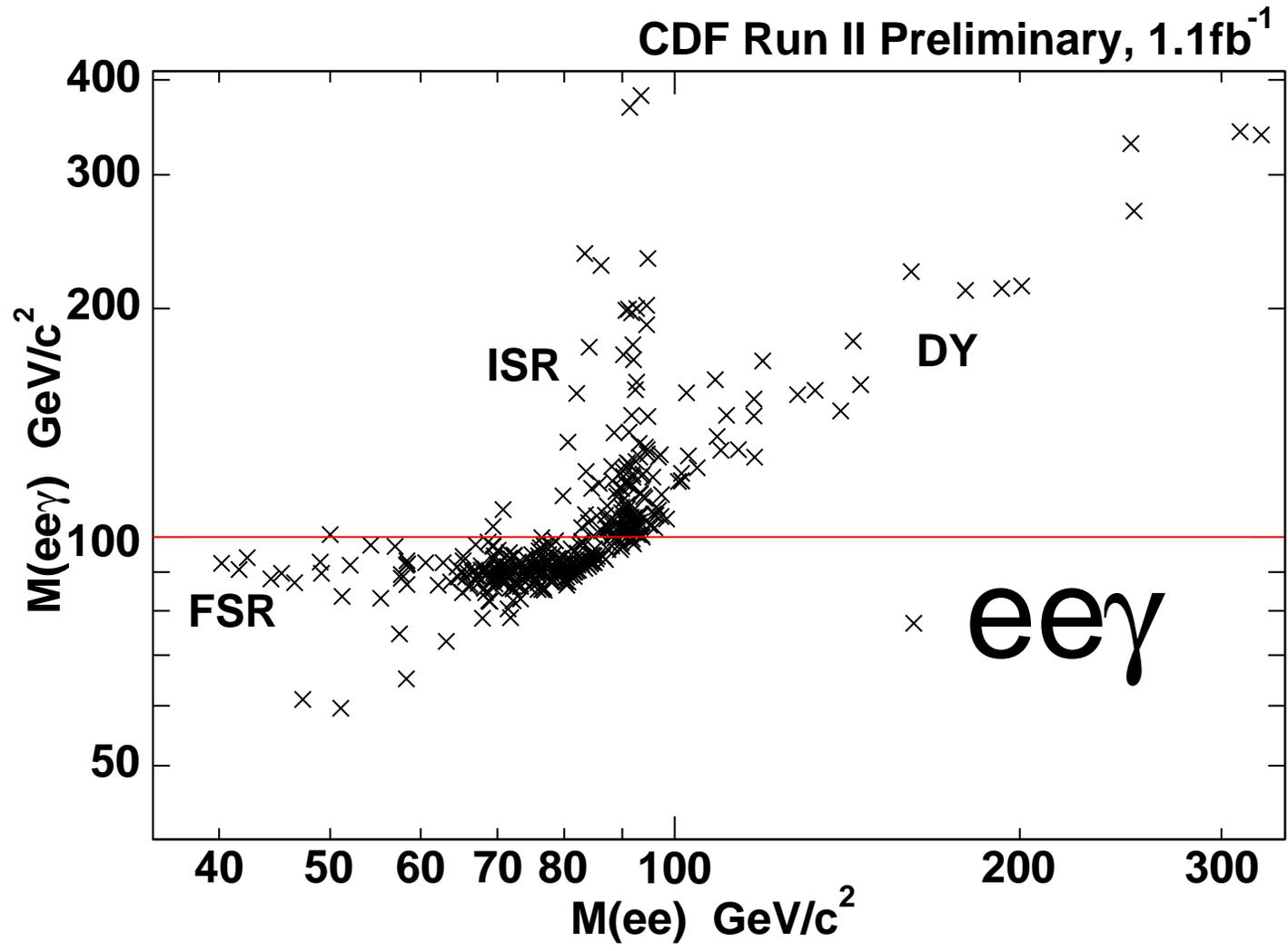
$$E_T^\gamma > 7 \text{ GeV}, \quad \Delta R_{e\gamma} > 0.7, \quad M_{ee} > 40 \text{ GeV}/c^2$$

	$e^+e^-\gamma$
N_{sig}	323.8 ± 17.3
N_{bkg}	51.0 ± 15.7
$N_{sig} + N_{bkg}$	374.8 ± 23.4
N_{data}	390
$A \times \epsilon$	6.5%
$\sigma(e^+e^-\gamma)$ (pb)	$4.9 \pm 0.3(stat) \pm 0.3(sys) \pm 0.3(lum)$
σ_{NLO}^{SM} (pb)	4.7 ± 0.4

Main sources of uncertainties on cross section:

- Signal Statistics : 6%
- Luminosity: 6%
- Background: 5 %

$p\bar{p} \rightarrow e^+e^-\gamma X$ Candidate Events



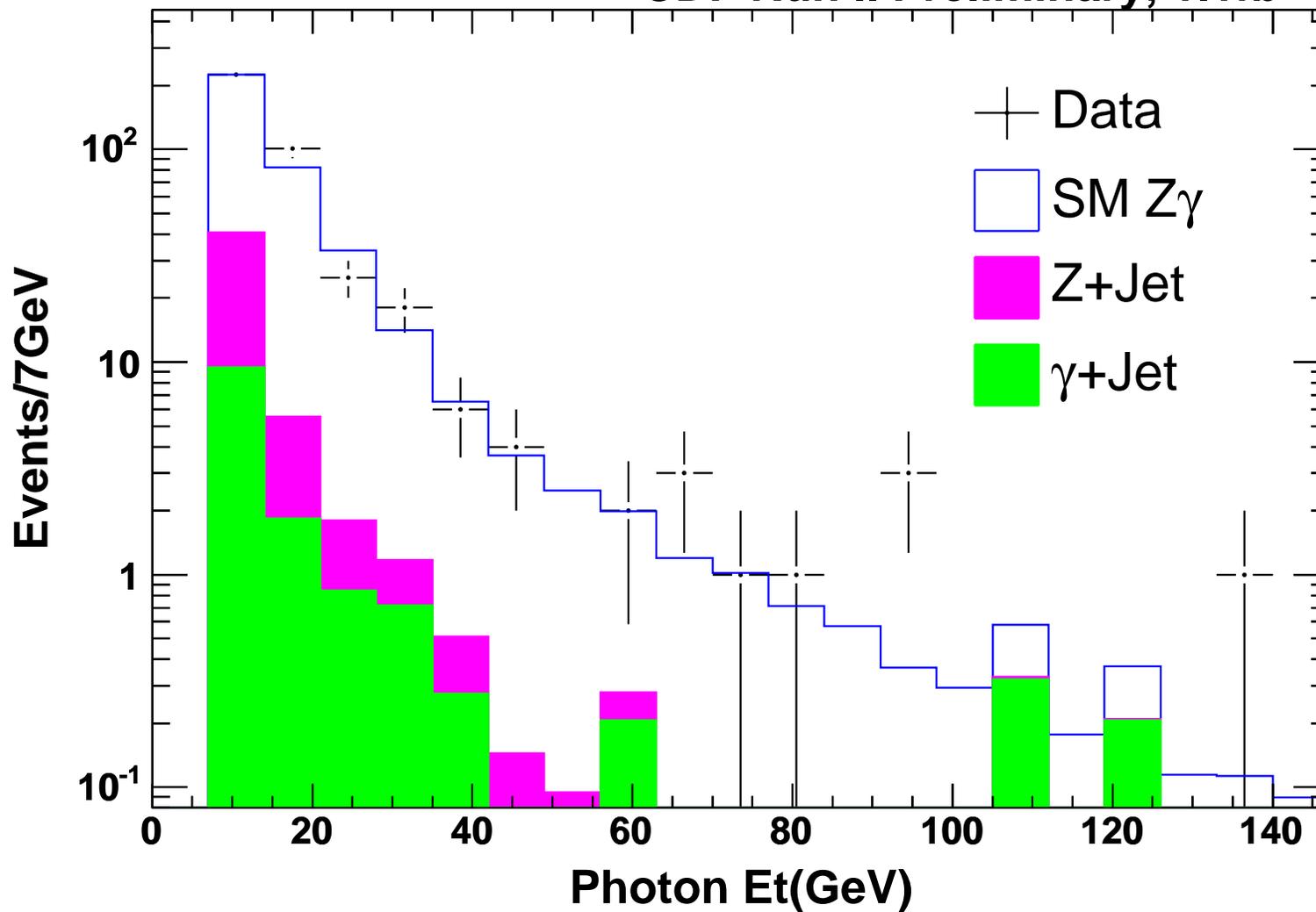
Measure ISR $Z\gamma$ Cross Section with 1.1 fb^{-1} of Data

- $E_T^\gamma > 7 \text{ GeV}$, $\Delta R_{e\gamma} > 0.7$, $M_{ee} > 40 \text{ GeV}/c^2$
- probe anomalous couplings: $M_{ee\gamma} > 100 \text{ GeV}/c^2$ (ISR dominate region)
- Data in good agreement with SM prediction

	$e^+e^-\gamma$
N_{sig}	117.2 ± 6.3
N_{bkg}	39.2 ± 12.4
$N_{sig} + N_{bkg}$	156.4 ± 13.9
N_{data}	154
$\sigma(e^+e^-\gamma)(\text{pb})$	$1.4 \pm 0.1(stat) \pm 0.2(sys) \pm 0.1(lum)$
$\sigma_{NLO}^{SM}(\text{pb})$	1.4 ± 0.1

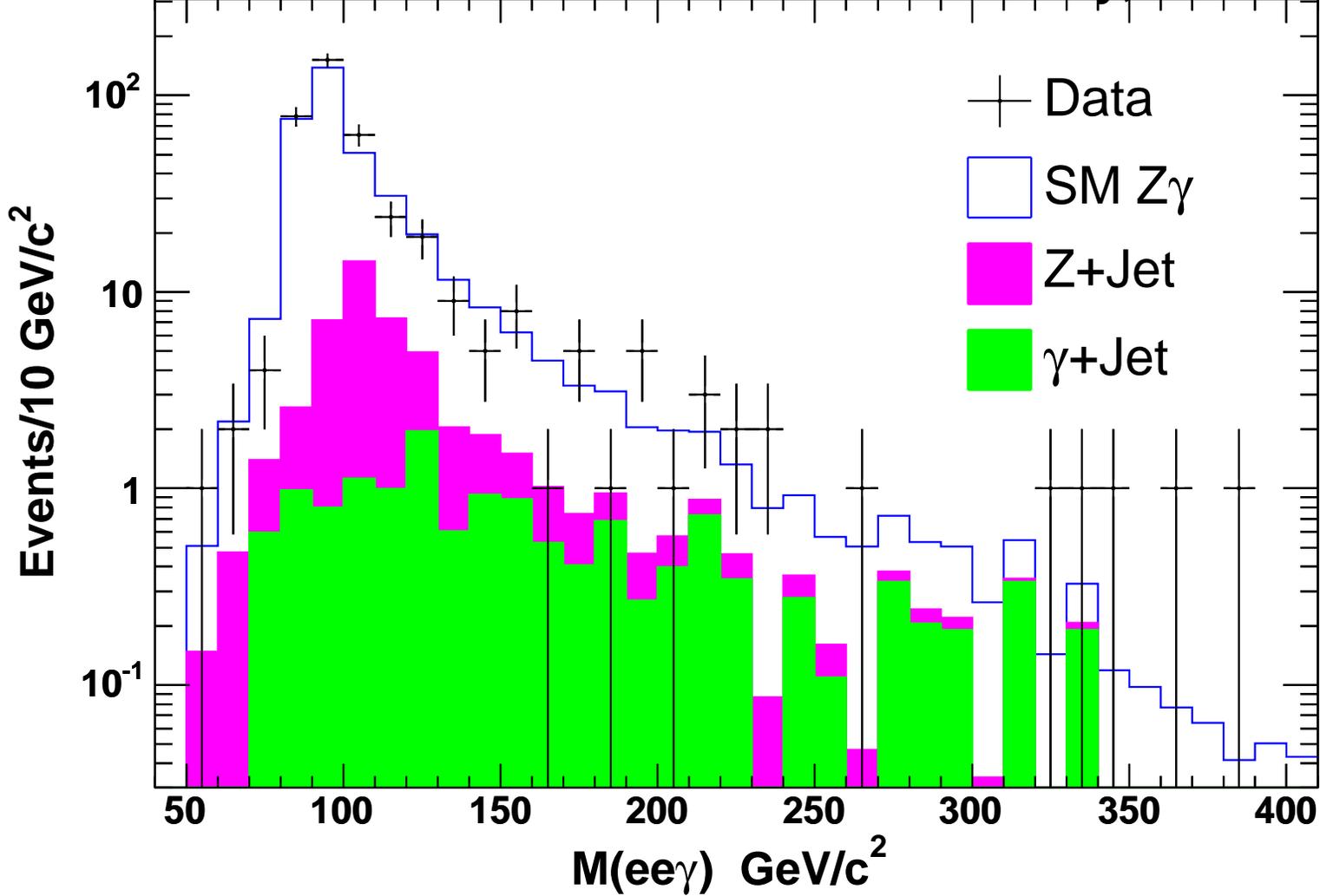
Photon Et Distribution

CDF Run II Preliminary, 1.1fb⁻¹



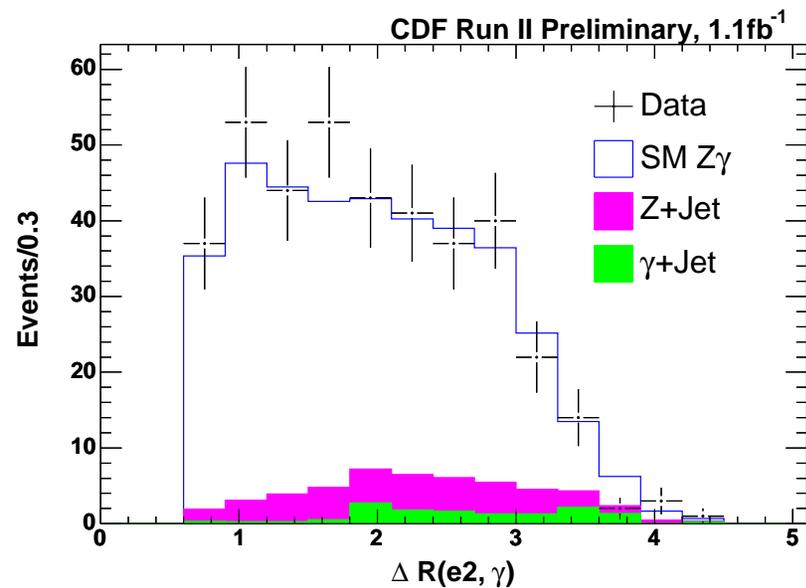
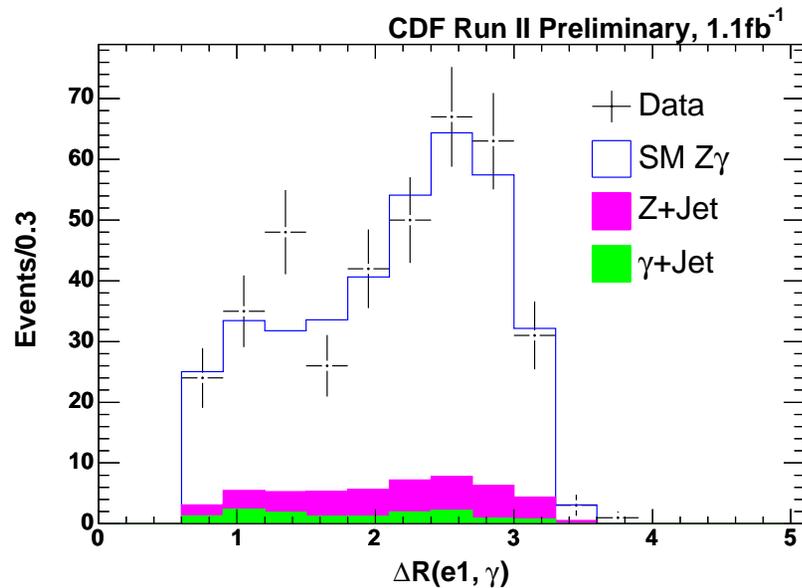
M(ee γ) Mass Distribution

CDF Run II Preliminary, 1.1 fb⁻¹

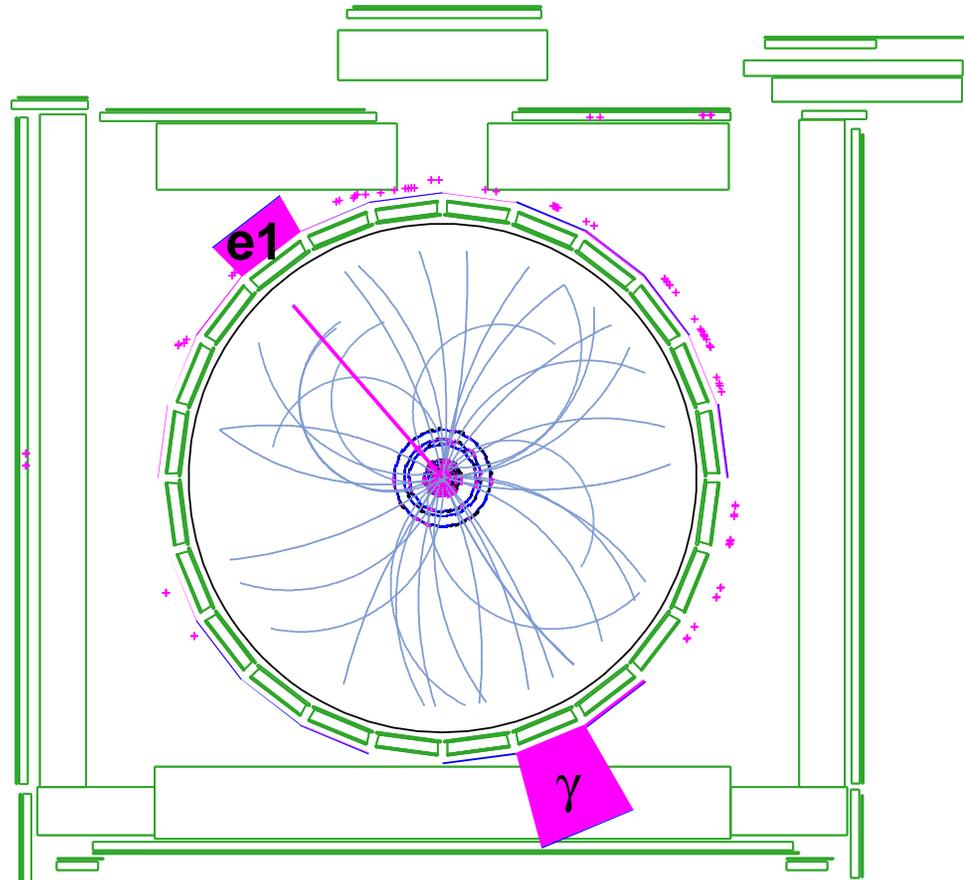


$\Delta R(e, \gamma)$ Distribution

- Electron - photon separation $\Delta R(e, \gamma)$
- $$\Delta R(e, \gamma) = \sqrt{((\eta_e - \eta_\gamma)^2 + (\phi_e - \phi_\gamma)^2)}$$



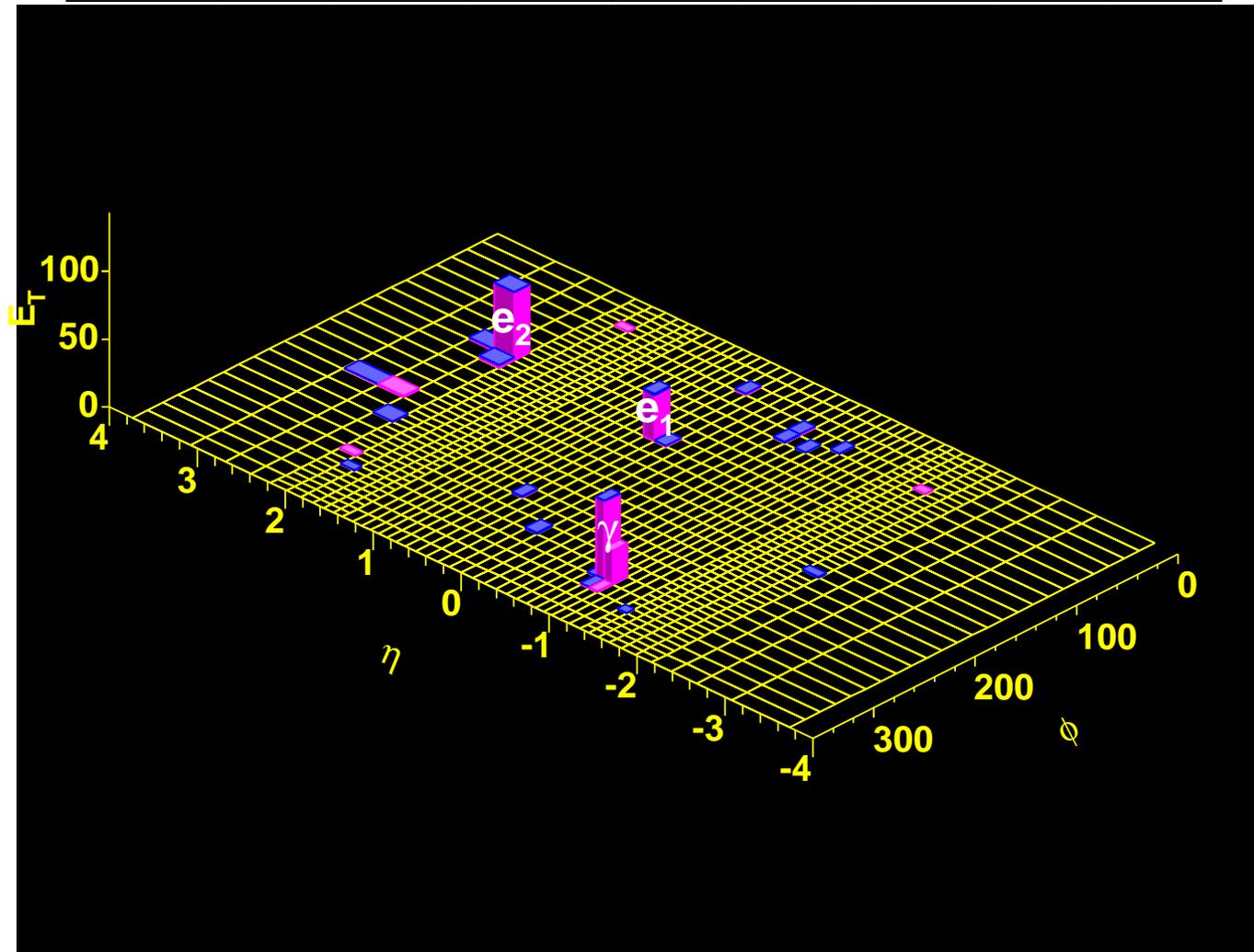
$M_{ee\gamma}$	E_T^γ	M_{ee}	$P_T^{ee\gamma}$	E_T^{e1}	E_T^{e2}	η^γ	η^{e1}	η^{e2}
381	83	93	9	35	56	-0.9	0.4	2.2



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The Highest $M_{ee\gamma}$ Event

$M_{ee\gamma}$	E_T^γ	M_{ee}	$P_T^{ee\gamma}$	E_T^{e1}	E_T^{e2}	η^γ	η^{e1}	η^{e2}
381	83	93	9	35	56	-0.9	0.4	2.2



Summary and Plans

Summary

- Loose Z selection criteria **doubles** acceptance
- $Z\gamma$ cross section agrees with SM prediction.
 - $\sigma^{obs} = 4.9 \pm 0.3(stat) \pm 0.3(sys) \pm 0.3(lum)$ pb
 - $\sigma^{th} = 4.7 \pm 0.4$ pb

High mass region, $M_{ee\gamma} > 100$ GeV/ c^2

- $\sigma^{obs} = 1.4 \pm 0.1(stat) \pm 0.2(sys) \pm 0.1(lum)$ pb
- $\sigma^{th} = 1.4 \pm 0.1$ pb

Coming next

- $Z\gamma$ measurement in μ channel
- Include photons in the forward detector region ($|\eta| < 2.8$)
- Study anomalous couplings